Techniques and Tools for PDV Applications

A Work In Progress

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Ed Daykin, Carlos Perez (NSTec)

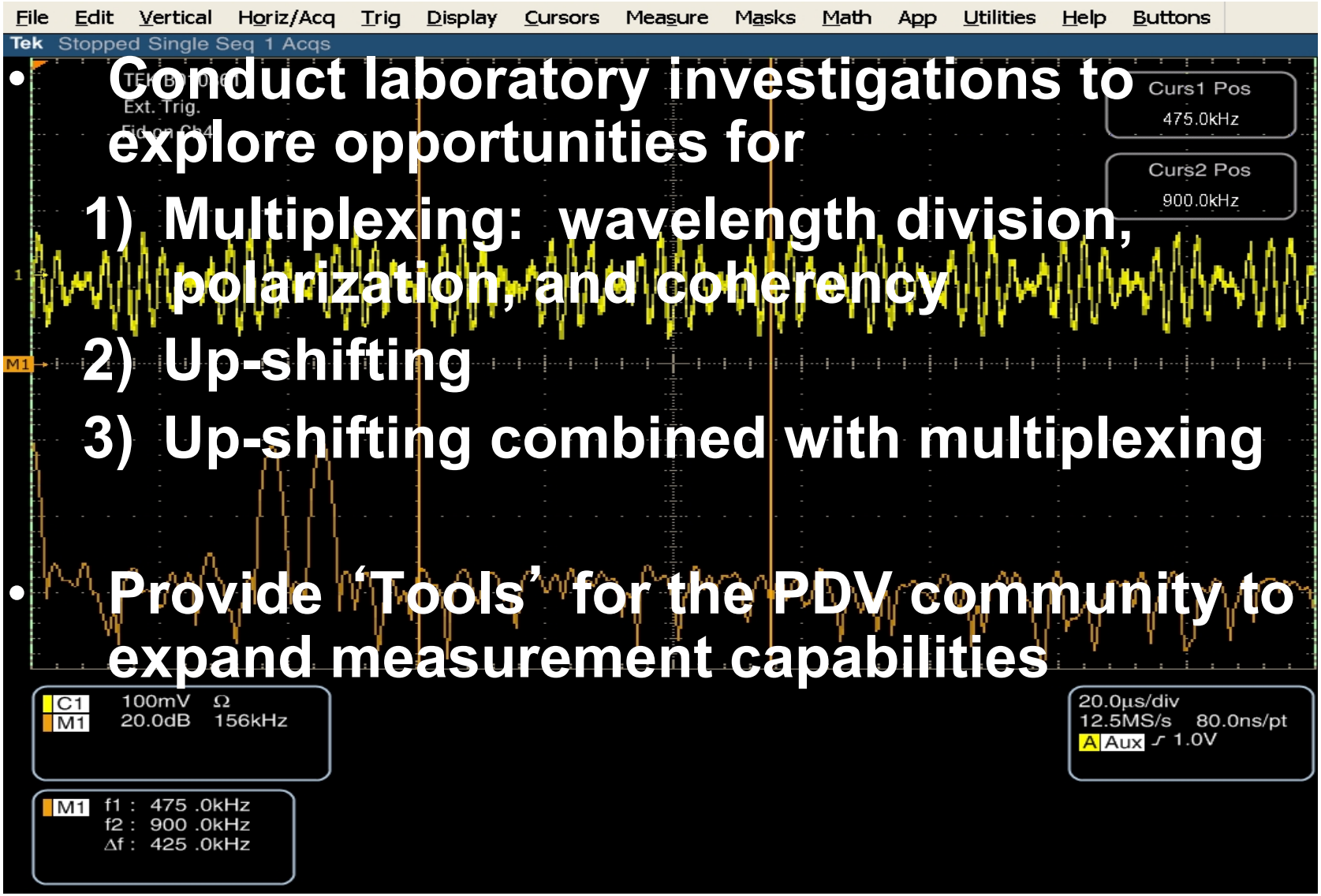
Collaborators Include:

Ted Strand, Tony Whitworth (LLNL)

Cenobio Gallegos (NSTec, LAO)

National Security Technologies LLC

Purpose of Investigations



- **Conduct laboratory investigations to explore opportunities for**
  1) **Multiplexing: wavelength division, polarization, and coherency**
  2) **Up-shifting**
  3) **Up-shifting combined with multiplexing**

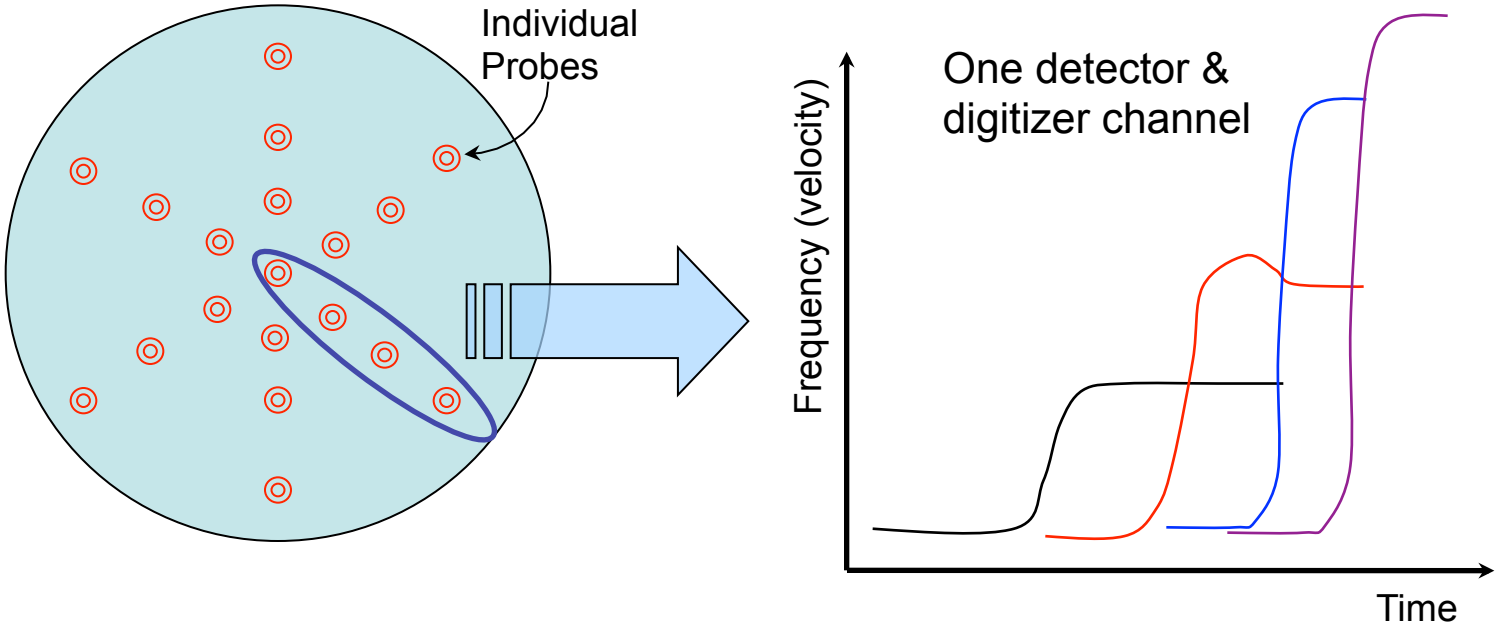
- **Provide 'Tools' for the PDV community to expand measurement capabilities**

Motivation and Applications

- **Motivation:** Expand Photonic Doppler Velocimetry (PDV) to Many-Point PDV (MPDV) by taking advantage of available bandwidth within recording system (i.e. make the most of high value digitizers) while maintaining data fidelity and system portability.

- **Principle Applications:**
  1) Experiments with ‘well defined symmetries’
  2) Experiments with ‘uniformity’ -- geometries where Line-VISAR has historically been applied

Many-Point PDV: Multiplexing Techniques for Experiments with 'Well Defined Symmetries'

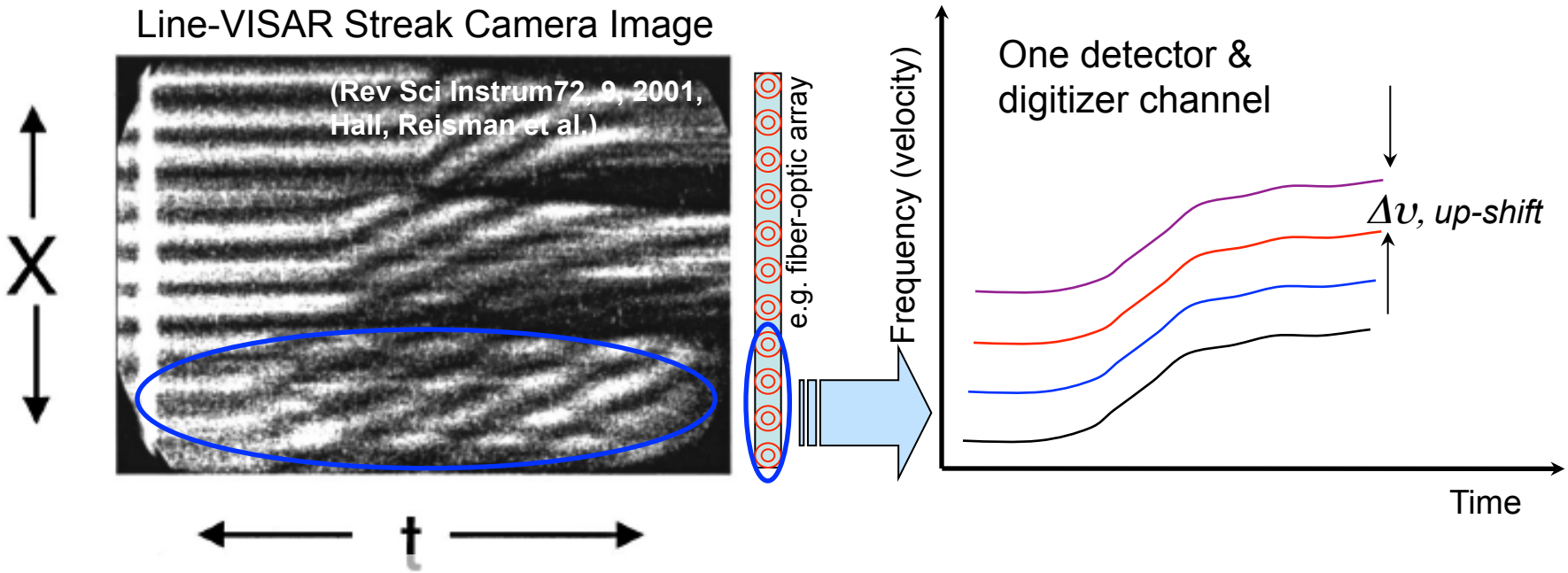


Candidate Multiplexing Techniques Include:

a) Wavelength Division Multiplexing (WDM)
b) Polarization Multiplexing (PM)
c) Coherency based (*Arago-Fresnel*)

Up-shifting is NOT necessary

Many-Point PDV: Multiplexing & Up-Shifting Techniques for Experiments with 'Uniformity'



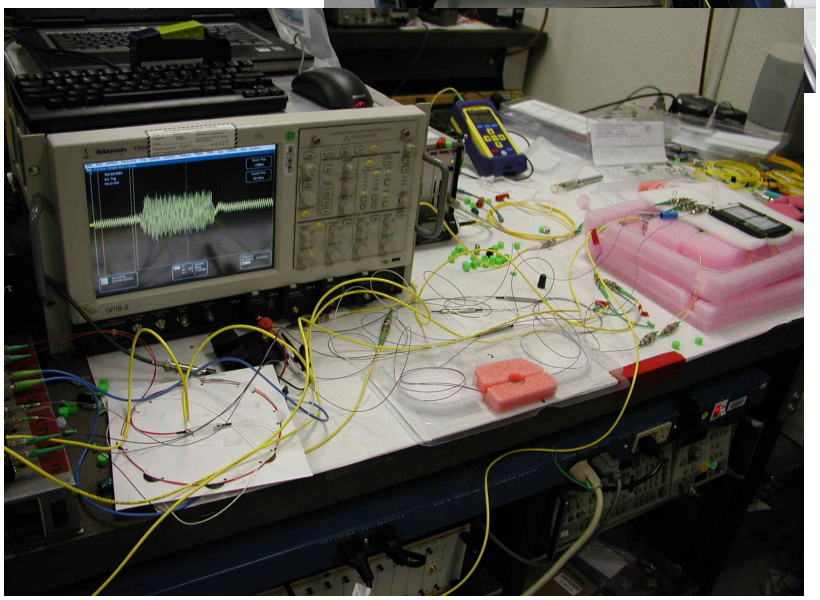
- Combine Multiplexing with Up-Shifting
- Candidate Up-Shifting Techniques Include:
  - a) Acousto-Optic (A-O) Modulation
  - b) Independent Laser(s)

Up-shifting IS necessary

We Investigated a Variety of Multiplexing and Up-Shifting Techniques

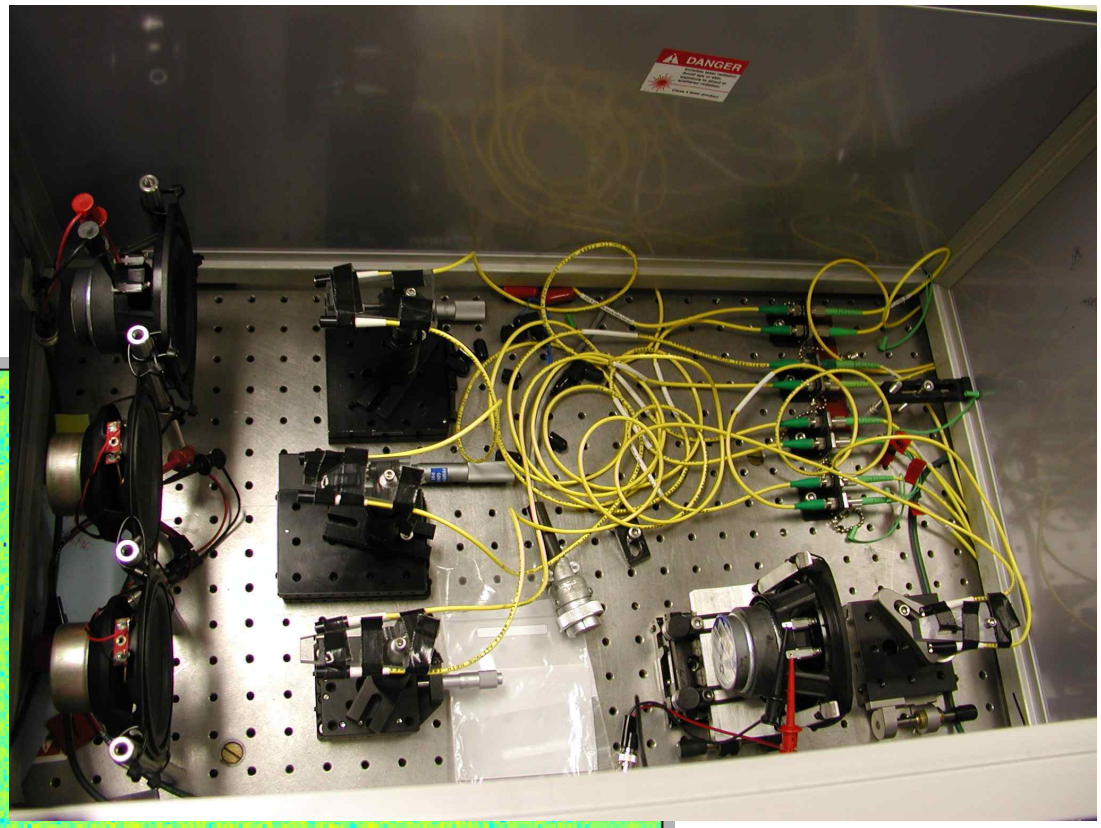
Questions

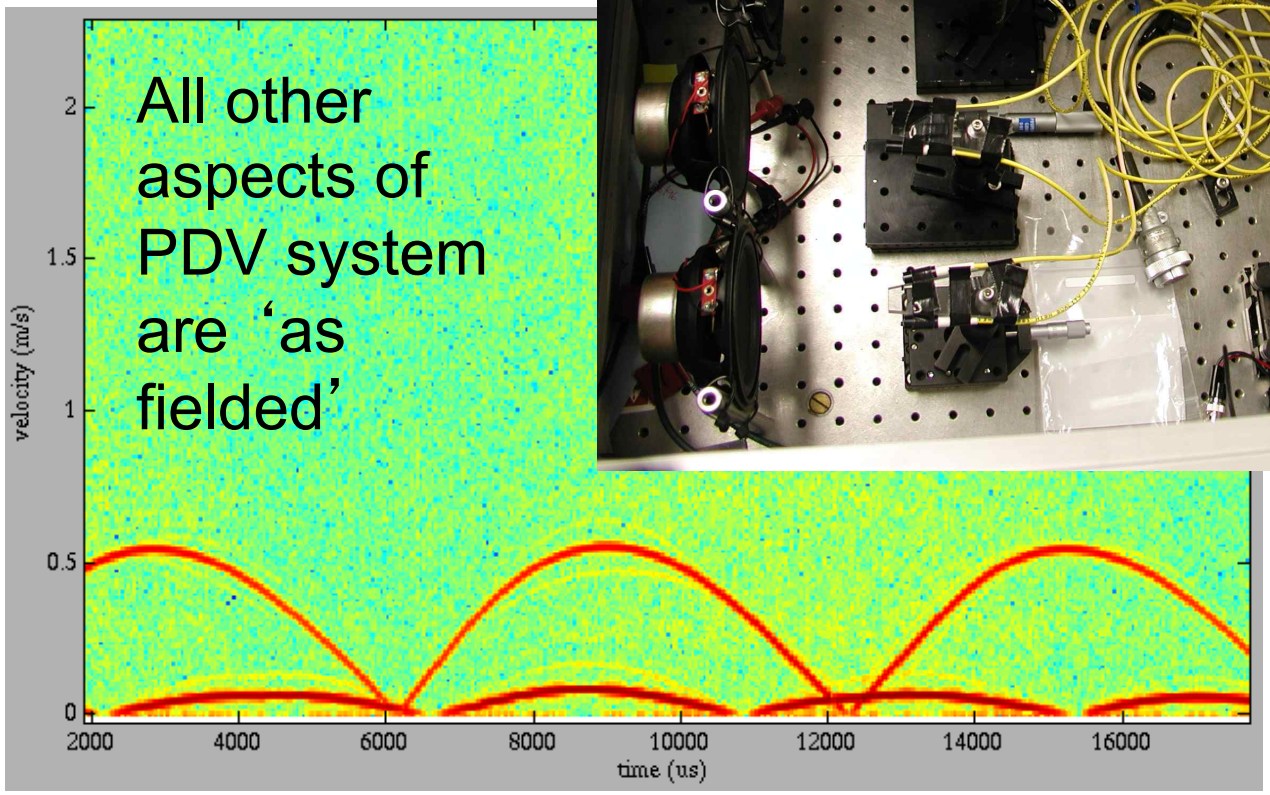
- Can we combine optical data channels (i.e. probes) without harmonic generation?
- How readily do orthogonal polarization components interact?
- How many channels … risk/reward?
- Limitations of FFT-based analysis?
- Is multiplexing economical?
- Polarization effects?
- Vendor comparisons?
- Other useful ‘tools’?



Laboratory Measurements were Conducted to Investigate Candidate Techniques

Used Audio Speakers to provide Doppler shifted signals

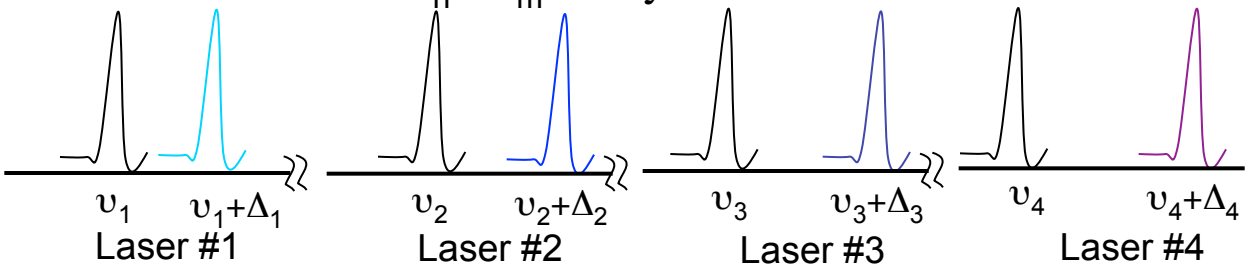




Tested both 'local' and 'remote' oscillator configurations

One Multiplexing Opportunity in Principle: Wavelength Division (with A-O Up-shifting)

Let $\upsilon_n - \upsilon_m >>$ System bandwidth



$\Delta_n \equiv n^{th}$ up-shift

e.g. A-O shifters
$\Delta_4 > \Delta_3 > \Delta_2 > \Delta_1$

Probe n: $\upsilon_{n,beat} = \upsilon_{n,\,Doppler} - (\upsilon_n + \Delta_n)$

	Digitizer Ch 1	Digitizer Ch 2	Digitizer Ch 3	Digitizer Ch 4
Laser #1	Probe #1	Probe #2	Probe #3	Probe #4
Laser #2	Probe #5	Probe #6	Probe #7	Probe #8
Laser #3	Probe #9	Probe #10	Probe #11	Probe #12
Laser #4	Probe #13	Probe #14	Probe #15	Probe #16

If Necessary (expt. case dependent)

Up-Shift

Δ_1 (or 0)

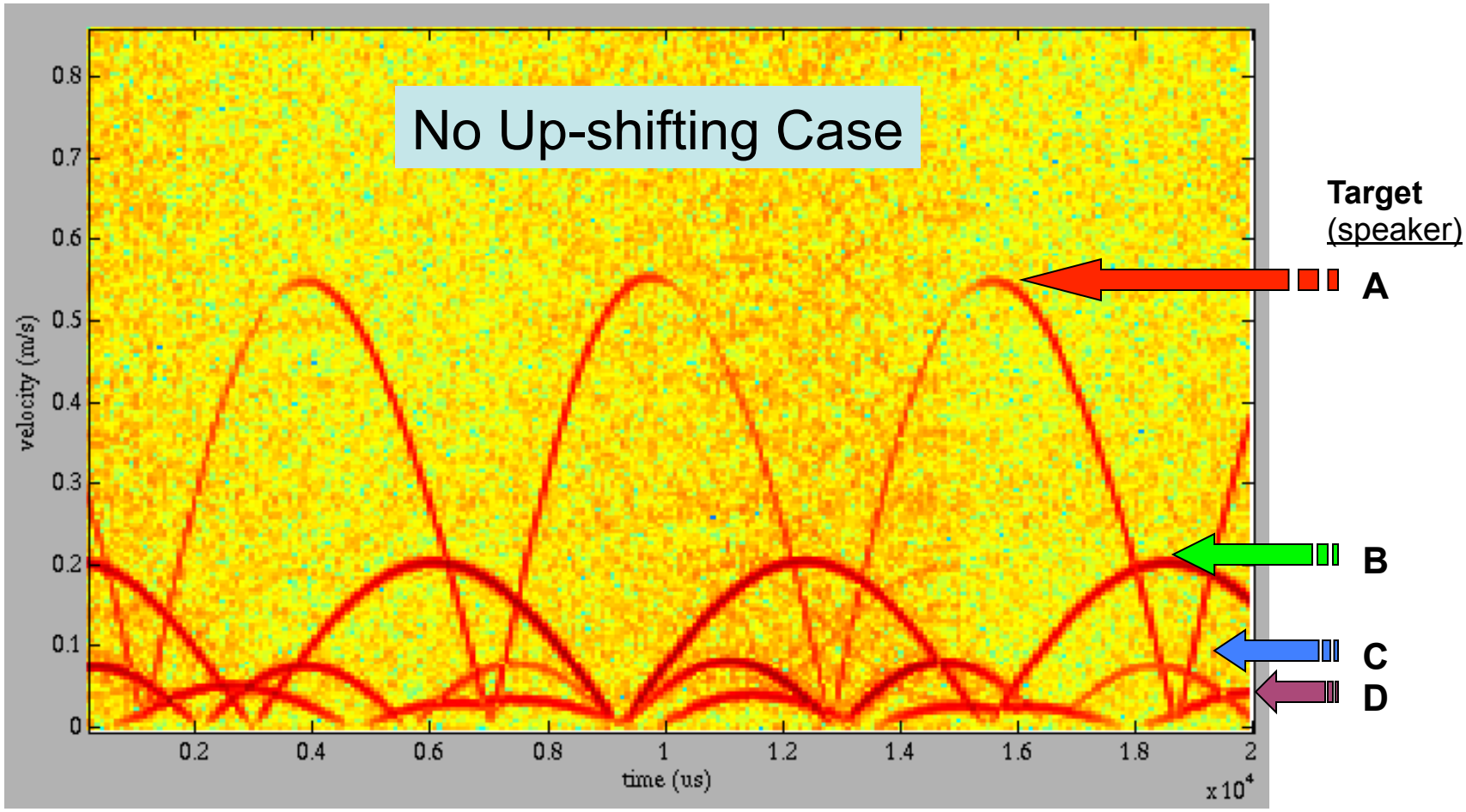
Δ_2

Δ_3

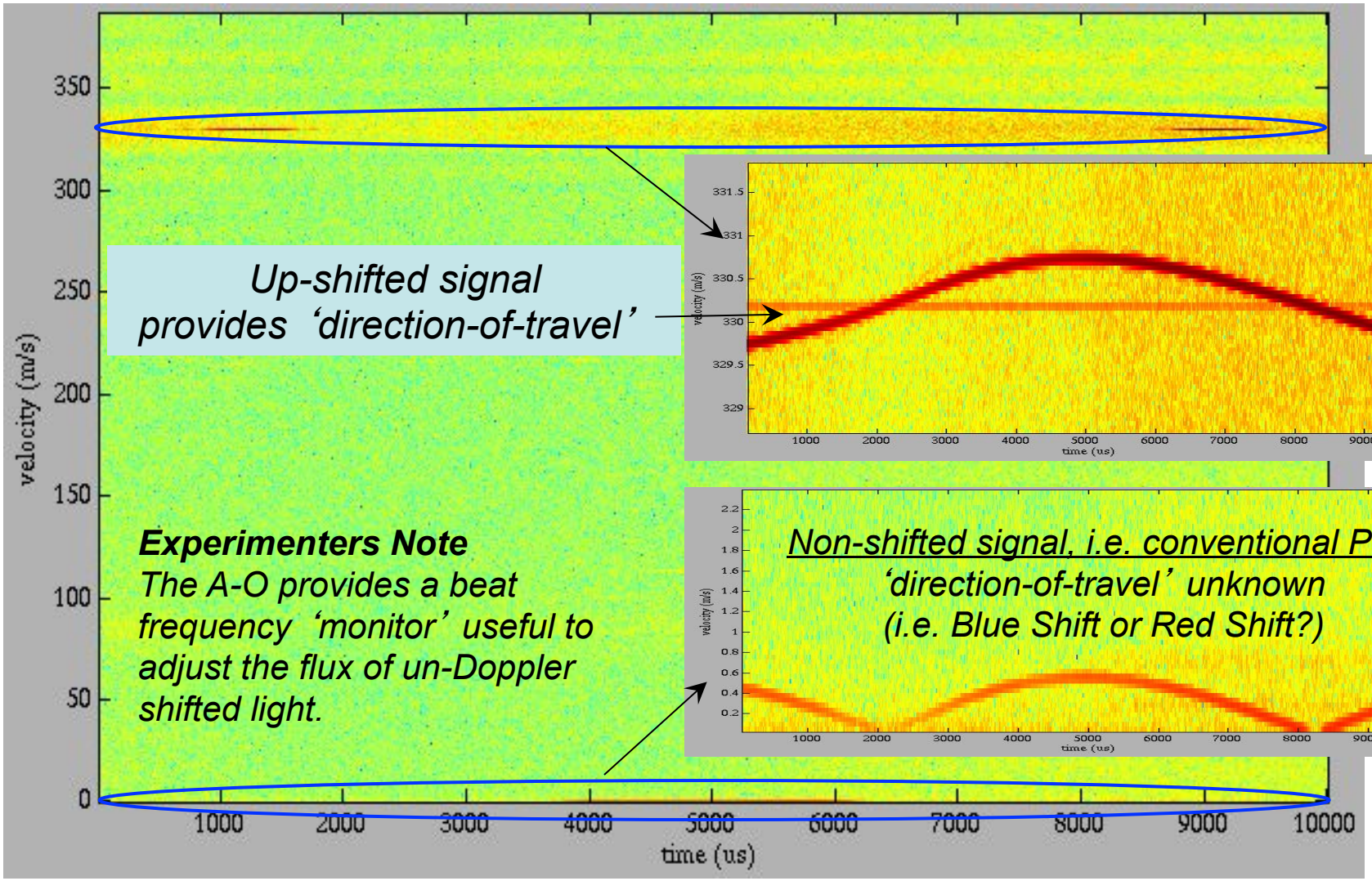
Δ_4

Wavelength Division Multiplexing Successfully Combined Data without Harmonics

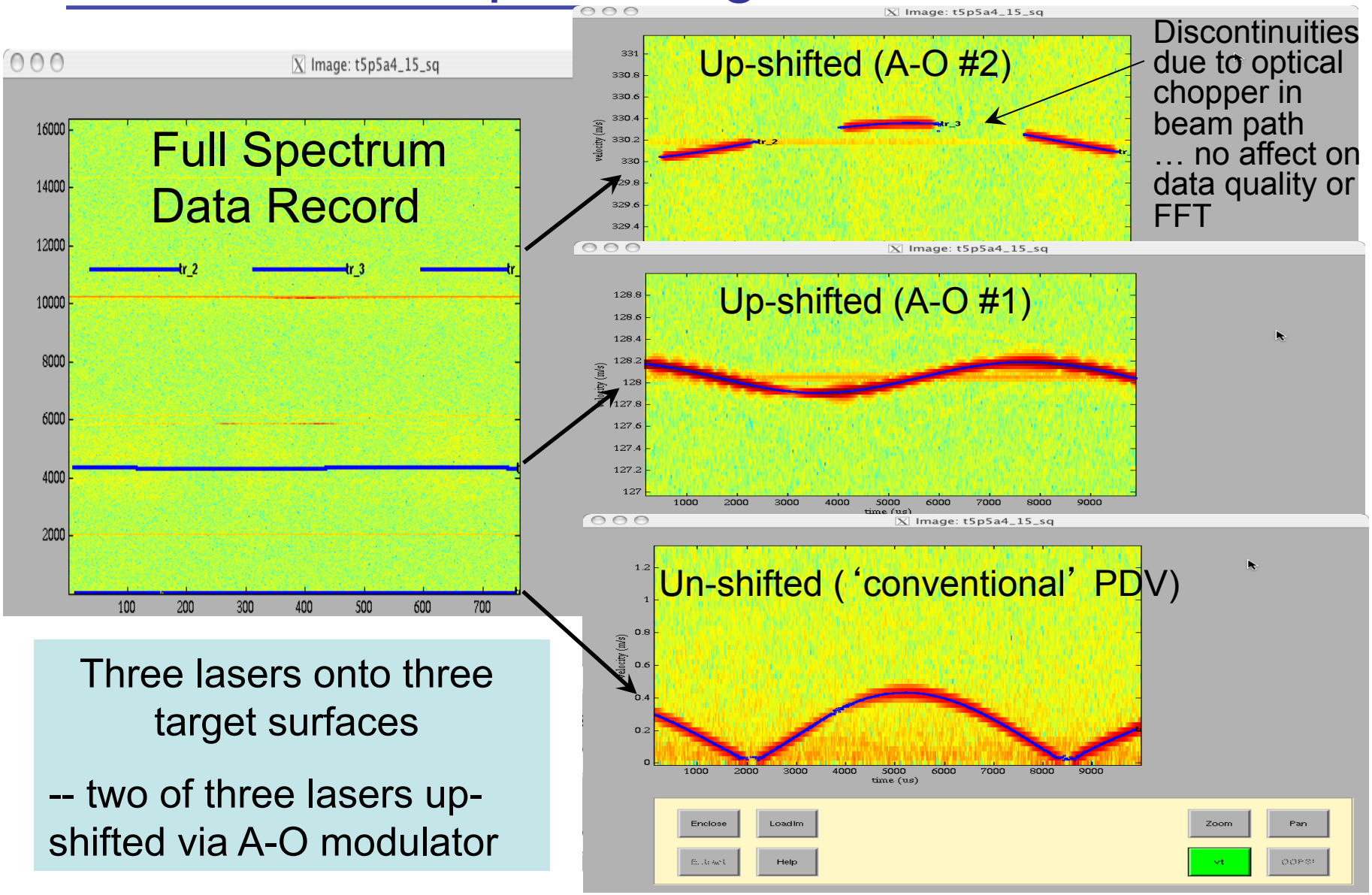
- Four Lasers onto four target surfaces (speakers) without polarization dependent components … No significant harmonic generation



Acousto-Optic Up-shifting Provides Multiplexing Opportunities … and more



Wavelength Division Multiplexing Combined with A-O Up-Shifting was Successful

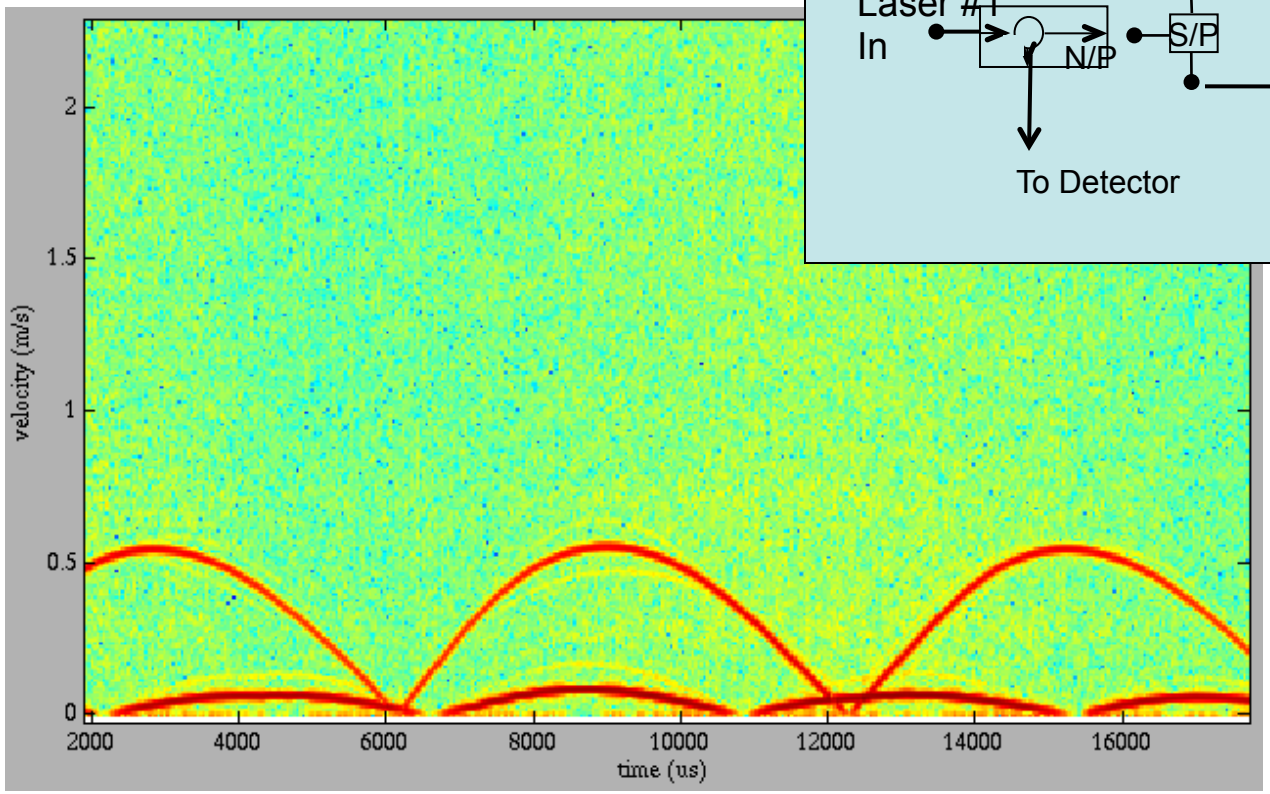


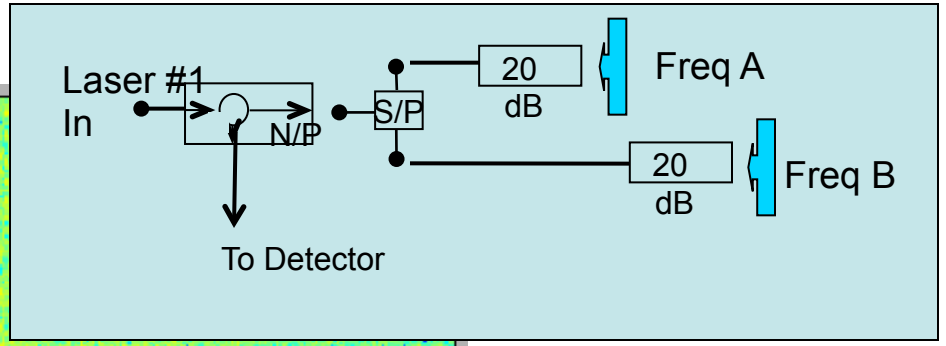
Three lasers onto three target surfaces

-- two of three lasers up-shifted via A-O modulator

Polarization Based Techniques Successfully Multiplexed Data Channels without Significant Harmonic Generation

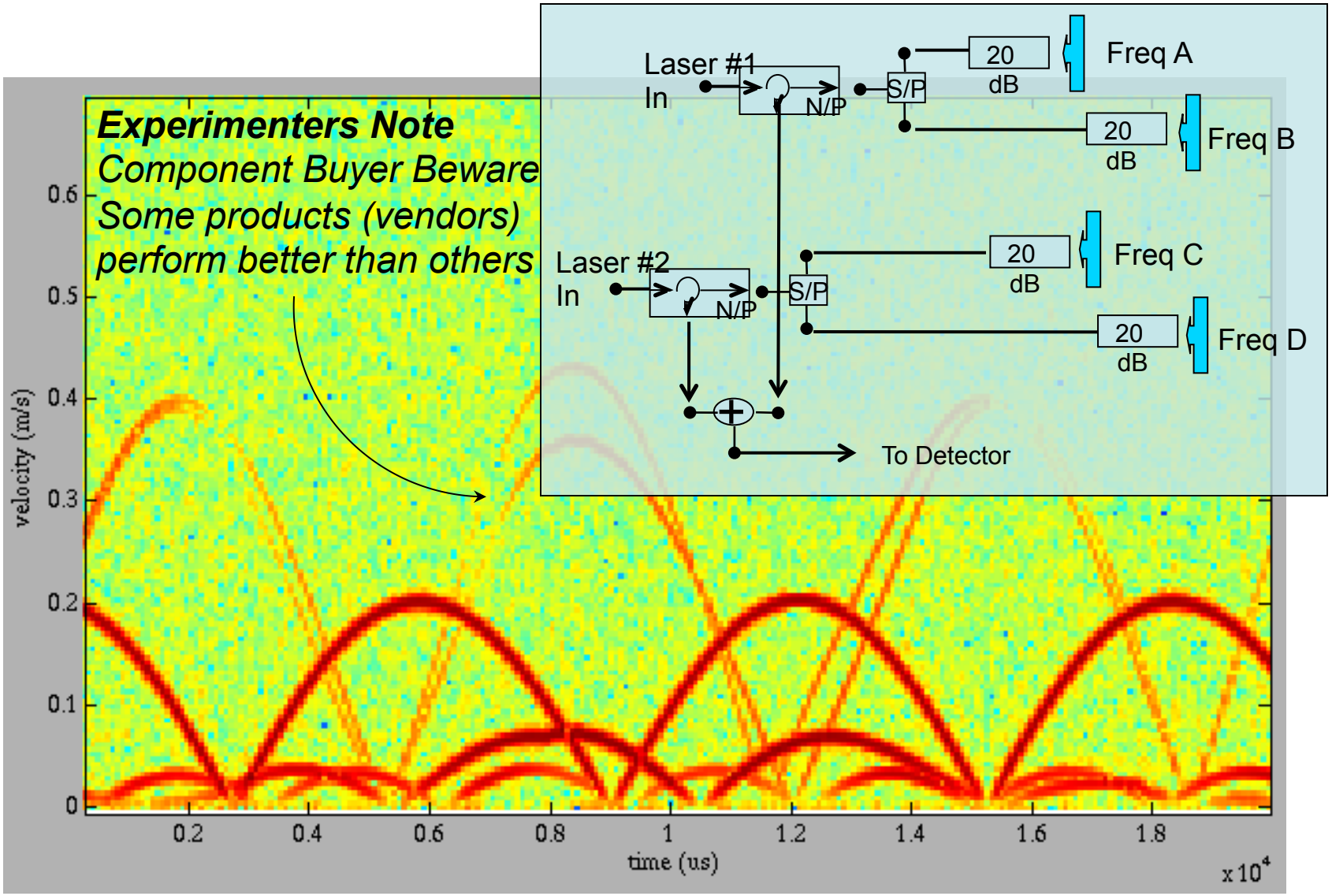
- Use of orthogonal polarization components readily doubles the total number of data channels.





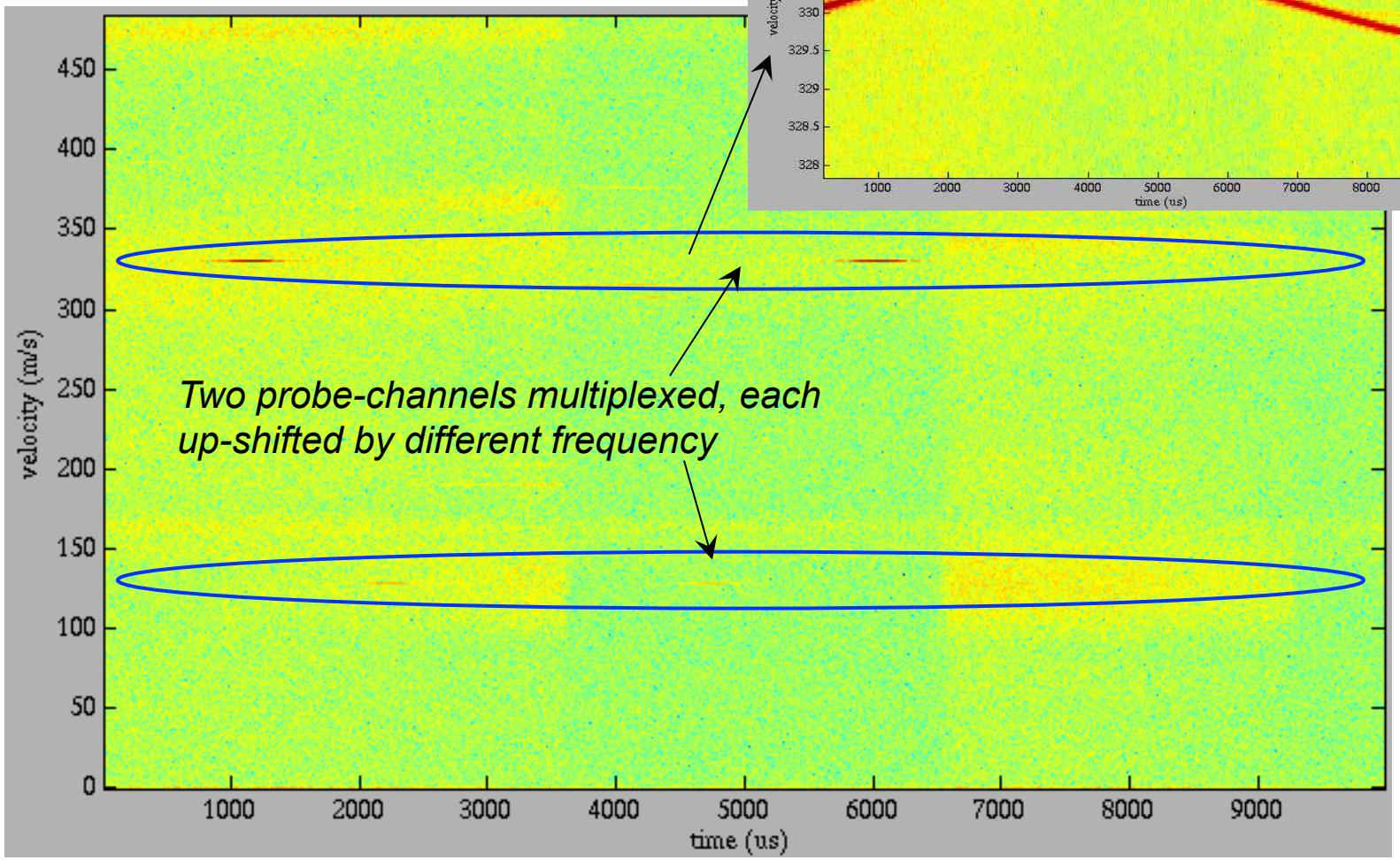
Experimenters Note
Orthogonal components do not interact (< 20 dB) for 'typical' configurations of fiber lengths and types.

Combination Polarization and Wavelength Division Multiplexing also Proved Promising

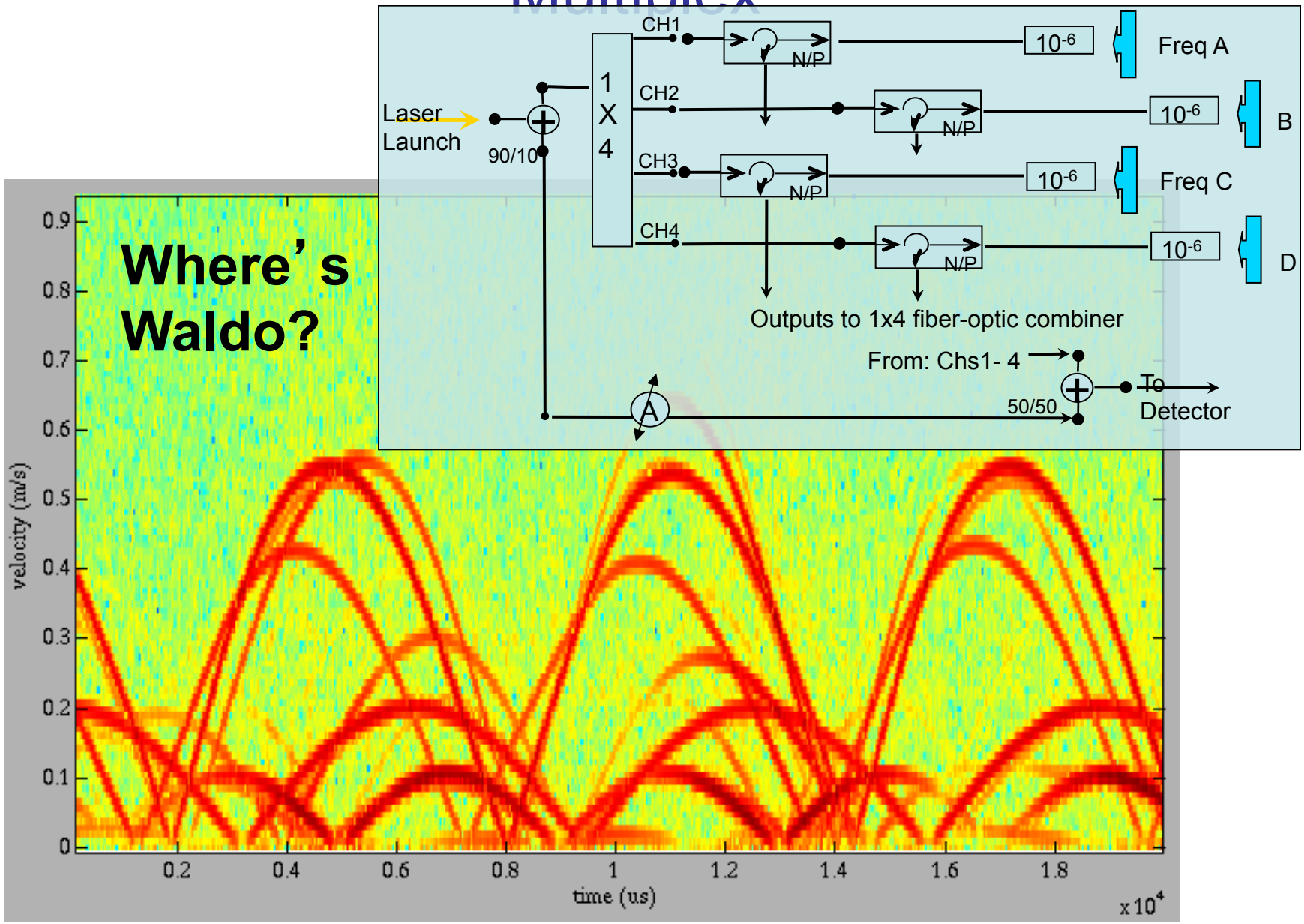


Polarization Multiplexing with Acousto-Optic Up-shifting

Single Laser, two probes, each up-shifted then multiplexed



It's Important to know how NOT to Multiplex



Associated Investigations: Tools and Techniques for the Diagnostic Community

- Determined Direction-of-Travel
- Demonstrated 'Differential Measurements'
- Demonstrated technique to 'make the most' of acousto-optic modulators: single and double pass configurations
- Demonstrated use of A-O to modulate reference signal; used as gauge for probe's signal return
- Investigated time-dependent polarization behavior of PDV measurements
- Analysis: explored FFT-based code capabilities
- Investigated use of independent laser as reference oscillator to generate up-shifted signals
- Conducted component (vendor) comparisons

MPDV Candidate Systems: Cost/Risk Analysis

Risk = risk of decreased data fidelity or data loss

	Symmetry Experiment	Line-PDV Experiment
High Value Experiment	4 Probes/Ch $13K/probe Risk: Low	4 Probes/Ch $15K/probe Risk: Low
Low Value Experiment	8 Probes/Ch $7K/probe Risk: Med	8 Probes/Ch $8K/probe Risk: Med

Conventional PDV System: ~ $36K/probe

(basis: one laser, one digitizer & four channels)

Summary of Experimental Results

- Successfully demonstrated validity and techniques to multiplex probes via
  1) Wavelength Division Multiplexing (WDM)
  2) Polarization Multiplexing (PM), and
  3) Combination PM and WDM multiplexing.
  - We combined (in lab tests) as many as eight probe-channels onto a single digitizer channel without significant generation of harmonics
- Successfully up-shifted via acousto-optical modulators
- Successfully combined both up-shifting and WDM/PM multiplexing
- Demonstrated a variety of associated tools, techniques and information useful to PDV experimental efforts.